Relative Influence of Sassafras, Black Locust, and Pines Upon Old-Field Soils

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Restoration of forests on 75 to 80 percent of the area of abandoned fields in the central hardwood region usually cannot be done directly with desirable hardwoods because of soil deterioration from cultivation and erosion. A preliminary crop is necessary that can endure site dryness, lay down a litter cover, and thereby make possible the restoration of surface soil structure and water-absorbing capacity. Sassafras, black locust, and pines, three species commonly performing pioneer functions, have been studied as soil conditioners. The functions performed by each in soil rehabilitation and their respective roles in reforestation are discussed.

DEFORESTATION and subsequent erosion accompanying faulty methods of tillage on many types of hilly land in the Central States have resulted in serious soil deterioration. An important area of some 10 million acres of deteriorated land is estimated to have been abandoned for agriculture in the central hardwood region.[2] A much larger forested area has been severely cut, burned, and pastured, but not cultivated. A great deal of this also could well be classed as abandoned land if present economic returns were the criterion of value. In the judgment of many conservationists, a forest cover should be restored to the 10 million acres either by planting or by natural regeneration.

Restoration of hardwood forests on most old-field land is difficult chiefly because of unfavorable soil conditions. Eroded old-field soil in general is too compact and deteriorated in structure to permit absorption of enough water for establishment and early growth of the more useful hardwoods. Changes in soil are effected essentially by vegetation; therefore some kind of preliminary cover that will survive and grow under the adverse soil conditions is necessary to bring about sufficient soil improvement to permit the establishment of a stand of acceptable composition.

Where the over-all situation permits a choice of tree species as a preliminary forest crop, economic returns are an important factor. Some planting sites already have a partial preliminary cover, the value of which lies largely in its soil-building properties and its silvicultural aid in favoring succession of more valuable species. Many conditions influence the role of preliminary forest crops; however, the purpose of this study was not an appraisal of their economic or other values but of their influence on soil conditions.

Sassafras, black locust, and pines were selected for study since they have been observed to function in the restoration of forest covers. Sassafras occurs over most of the region but not in dense stands of sufficient size to function as a preliminary forest cover except in southern Indiana, southern Illinois, southern Missouri, and northern Arkansas. It regenerates naturally in old fields and spreads readily enough on some areas to be considered a nuisance in corn fields. The species has only limited economic value. Regeneration of valuable hardwoods has been observed under sassafras. Clumps of it in abandoned fields therefore provide opportunity for interplanting or underplanting. Black locust has been planted throughout the entire region for posts and for erosion control. The species has been advocated as a tree crop to prepare the soil for succession of other hardwoods largely because it is a legume and consequently a fixer of atmospheric nitrogen. Pines are able to become established and grow with much less soil moisture and fertility than is required by hardwoods, hence are very useful as a first crop on dry abandoned land. Succession of native hardwoods has been observed in pine stands regenerated from old-field soils. Such succession of hardwoods not found on old fields except after pine establishment indicates soil improvement by the preliminary stand.

The study was carried out on the Kaskaskia Experimental Forest in northern Hardin County, Illinois, the Morgan-Monroe State Forest in Morgan and Monroe Counties, Indiana, the Brown County State Park, in Brown County, Indiana, and the Shawnee State Forest in Adams and Scioto Counties, Ohio. All these areas include lands typical of abandoned fields. Natural stands of sassafras and both natural and planted stands of locust and pines of various even ages were studied. All of these areas were forested primarily with hardwoods prior to their use for agriculture. Altogether, 27 stands of sassafras,

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24 of black locust, and 11 of pines (including shortleaf, eastern white, red, Austrian, and Scotch) were examined. The ages of the sassafras and black locust stands ranged from 2 to 35 years and those of the pine stands from 8 to 30 years.

Methods of Study

The criteria of soil recovery are few and simple in their major aspects. Soil deterioration results mainly from removal by erosion of the porous fertile surface layer and its protective litter cover; soil recovery involves their restoration. In this study soils of abandoned fields were compared with soils of areas originally in the same state of deterioration but subsequently planted to or regenerated naturally with sassafras, black locust, or pines. The measures of soil recovery dealt with were (a) total quantity of litter and its calcium and nitrogen content, (b) quantity of organic matter and nitrogen accumulated in the upper mineral soil attributable to recovery since reforestation, and (c) change in rate of surface-water infiltration since reforestation. Each woodland plot was located near an abandoned field to provide opportunity for comparing it with a field plot maching it in soil, aspect, and slope.

The reforested sample areas were selected in fully stocked stands with uniform cover and absence of humps and hollows in the soil surface. The soil in each of the sassafras, black locust, and older pine stands was sampled on six 1-foot squares selected at random. On each of four squares, infiltration tests were made, and from the remaining two the litter was carefully removed and samples taken of the A_1 and A_2 horizons.

Sampling of soil and litter on the young pine plots where crowns were not closed differed from that on the older plots only to the extent that it was confined to the area representing the projection of the crown on the ground. An adjustment was then made to the acre basis depending on the percentage of the total ground area covered with pine needle litter.

Litter weights were reduced to the oven-dry acre basis. All litter data were corrected for soil contamination, a factor highly important in weight estimate and analysis of forest litter. A sample of oven-dry litter was burned to ash. Hydrochloric acid diluted with an equal volume of water was used to dissolve the ash fraction, which was removed by filtering. By controlling the acid temperature and the treatment time, insignificant quantities of silica and oxides of iron and aluminum were dissolved from the soil fraction.

Organic matter incorporated in the mineral soil was determined by burning off the combustible portion of weighed dried samples. The objectionable features of determining loss of organic matter on ignition such as the complicating effects of combined water, carbon dioxide, and volatile compounds were obviated by subtracting loss on ignition of the A_2-horizon soil from that of the A_1-horizon or surface soil immediately over the A_2. This procedure was valid because when an area has been plowed and cultivated repeatedly, the surface 2 inches of mineral soil and the soil immediately below it do not differ markedly in loss on ignition other than that attributable to organic matter from plant residues incorporated after cessation of cultivation. The same is true of organically combined nitrogen. Differences in organic matter or nitrogen accretion betweeen forest-regenerated and open old-field soil following abandonment were accordingly secured by subtracting the accretion in the field surface soil thus determined from that in the adjacent wooded surface soil.

Differences in ratio of litter to organic matter incorporation and in relative abundance of secondary vegetation under sassafras and black locust became apparent early in the investigation. Examination of these differences was made in a complete organic-matter inventory on one plot of each of two species. Two 20-foot by 20-foot plots, fully stocked and on the same general soil area, were selected for study. The sassafras stand was 9 years old, the black locust 12. In late summer all trees were cut from the two plots, and the leaves plucked, dried, and weighed. The litter was gathered from the whole of each 400-square-foot area, dried and weighed; and samples of the A_1 and A_2 soil horizons were dried and tested for organic-matter content. Live annuals, dead annuals, and dead twigs were gathered, dried, and weighed.

Infiltration tests were made by an accepted sprinkling method. These were made when soils had average or less than average field moisture content. No test was made sooner than 24 hours after a heavy rain. The equilibrium runoff volume for a 5-minute period was subtracted from the volume added each 5 minutes to determine the approximately constant volume of water ab-

sorbed by the soil. This infiltration volume was reduced to inches per hour.

Results

LITTER

Determination of weight of litter accumulated is important because litter is the forest's most important source of organic matter.

Weights of clean, oven-dry litter are summarized in Table 1 by species and age of stand. Litter weight under sassafras was high for the young age class and increased only moderately after the age of 2 to 5 years. Litter weight under black locust also was high at early stand age, but increased up to the 17-year to 20-year age when apparently it became relatively constant. Weight of pine litter was very low in the young age class; increased slowly during the 6-year to 10-year period when its average was only one-half that of sassafras and one-third that of black locust; then increased very rapidly during the 11-year to 16-year period when its average became three times that of sassafras and twice that of black locust of the same age group. In the 21-year to 35-year age class when litter weights presumably had become fairly constant, the weights for sassafras, black locust, and pines were respectively about 7,000, 10,000, and 20,000 pounds per acre.

The differences in litter weights of pine and of the two hardwoods at the early ages are attributable in part to slowness of young pine in dropping its needles, but more to density of stocking. The pine was planted in rows with a 6-by-6-foot spacing, whereas the hardwoods were natural stands with densities much greater than that represented by a 6-by-6-foot spacing. The crown canopy of the hardwoods closed much earlier because of their greater density than did that of the pines, in the stands sampled for this study.

ORGANIC MATTER ACCUMULATION

Out of 19 matched sassafras and field plot soils, the former all contained more organic matter than did the latter. Out of 16 similarly matched black locust plot soils, 9 field plot soils had more organic matter than had forested plot soils; and of 11 matched pine and field plot soils, 7 field plot soils had more organic matter than had associated woods plot soils. The average accumulation of organic matter on the basis of total soil weight in the upper 2 inches of mineral soil under sassafras was 0.6 percent more than that accumulated in the soil of adjacent old fields. Under similarly comparable conditions the surface soils under both black locust and pines showed no significant increases in organic-matter content over the increases of adjacent old-field soils.

Table 1.—Weight Per Acre of Clean Oven-Dry Litter by Age of Trees in Stands of Sassafras, Black Locust, and Pines

Age class	Weight of over-dry liter		
	Sassafras	Black locust	Pines
Years	*Pounds*	*Pounds*	*Pounds*
2- 5	5,000	5,400	.....
6-10	5,500	8,600	2,700
11-16	6,400	8,300	17,800
17-20	7,400	12,300	.....
21-35	6,800	10,200	20,600

The 0.6 percent gain under sassafras is equivalent to 6,000 pounds per acre for this kind of forest soil to a depth of 4 inches, or to 3,000 pounds per acre to a depth of 2 inches. This gain represents a substantial step toward rehabilitation because it is equivalent to from 10 to 20 percent of the organic matter found in well-developed woods soil of similar location. It is significant that this very appreciable step toward restoration took place within a period of 35 years.

TOTAL ORGANIC MATTER

A complete inventory by kind and weight of each type of organic matter on two plots regenerated from old fields is given in Table 2. The significant items in this table are the practically equal weights of leaves on trees of the two species, the greater accumulation of litter and weight of live annuals under the black locust stand than under the sassafras stand, and the greater weight of organic matter incorporated into the mineral soil under sassafras.

Table 2.—Total Oven-Dry Organic Matter Per Acre in a Sassafras and a Black Locust Stand and Soil

Form in which organic matter occurred	Oven-dry organic matter	
	12-year-old sassafras	9-year-old black locust
	Pounds	*Pounds*
Leaves on trees	2,323	2,372
Litter	5,573	7,558
Live annuals	159	1,082
Dead annuals	0	188
Dead twigs	1,020	1,881
Total nonmineralized	9,075	13,081
Mineralized in A_1 soil horizon	6,680	640
Total organic matter	15,755	13,721

NITROGEN CHANGES

Out of 8 sassafras stands and matched fields, 7 showed an increase in total nitrogen content of the surface mineral soil of woods over field; only 1 showed a decrease. Under similar conditions of comparison, 8 out of 16 black locust woods soils showed an increase, and 8 a decrease. Comparison of gain in nitrogen content of soil under sassafras with gain under old-field vegetation shows that the average quantity of relatively stable nitrogen added to the surface soil by sassafras is greater than that quantity added by old-field vegetation. The difference is a real one not explainable by sampling errors. Similar comparison of soil under black locust with soil under adjacent old-field vegetation shows no real difference. This does not mean that no nitrogen is liberated from black locust. The contrary is true, but it does mean that the nitrogen liberated is lost to the soil either by leaching or absorption by associated plants.

The data show also that increased accumulation of soil nitrogen is accompanied by increased accumulation of organic matter. Since black locust is a legume with highly nitrogenous litter, its failure to cause accumulation of relatively stable nitrogenous substances is clearly caused by absence of litter incorporation. The absence of significant organic matter in the mineral soil under black locust is evidence of its rapid decomposition. When a depth of litter is reached that ensures favorable moisture content, a quantity of litter equivalent to that of a yearly leaf fall decomposes each year on the soil surface.

One ton of black locust litter with 2.81 percent nitrogen liberates yearly about 56 pounds of nitrogen equivalent to 264 pounds of pure dry ammonium sulfate. Such an abundance of readily available nitrogen has a bearing on the functions of black locust as a preliminary crop. The species fills a special silvicultural role of great usefulness if certain precautions to be discussed later are observed.

Table 3.—Calcium and Nitrogen Content of Litter in Stands of Sassafras, Black Locust, and Pines

Species	Calcium	Total nitrogen
	Percent	*Percent*
Sassafras	1.57±0.054	1.59±0.053
Black locust	3.22±0.115	2.81±0.37
Pines		
Scotch	1.66± .17	2.29± .21
Red	1.16± .20	
Shortleaf	0.69± .06	0.99± .12
White	1.72± .08	1.59± .09
Austrian	1.56± .30	1.23
All pines	1.36	1.52

Calcium and nitrogen contents of sassafras, black locust, and pine litter are given in Table 3. Sassafras and pine litters have approximately the same calcium and nitrogen percentages, whereas black locust has roughly twice as much as either. Considerable variation in calcium and nitrogen percentage was found to exist between the litters of the various species of pine.

WATER INFILTRATION

Infiltration rates of soil supporting stands of sassafras were higher than those of abandoned fields by a highly significant difference, and this difference increased with age of the stand. Infiltration rate of the soil under the 11-year to 20-year-old black locust stands was higher than that of the soil under the 0-year to 10-year-old group; but infiltration rate of the soil of the 21-year to 40-year-old group was less than that of the 11-year to 20-year-old group.

Decrease in infiltration under the older locust stands is attributable to inclusion of several decadent isolated stands under which grass sod had developed. These older stands were not favorably located for regeneration by native hardwoods because of absence of natural seed sources. When they became decadent and the crowns opened, grass entered the forest floor under the stimulus of increased light and abundant nitrogen from the locust litter.

In a previous study,[3] the soil of ten pine plantations in Ohio varying from 12 to 23 years in quantity of water absorbed in the first two 5-minute periods in the current study as beginning rate, the respective ratios of woods soil to field soil infiltration rate were sassafras 2, and black locust 1.2.

Under average or better growing conditions, sassafras and locust lay down a complete cover of litter much earlier than do most pines and effect earlier improvement in surface soil structure. But after 10 to 15 years, soils under pine stands of similar density exhibit equally as good improvement in surface soil structure as do hardwood soils. Protection of the soil surface is a prime requisite for development of soil porosity, hence one litter cover probably serves as well as another if present in equal thickness. More pine age showed a beginning infiltration rate of 4.4 times that of adjacent field soil. By taking the

[3] Auten, John T. Porosity and water absorption of forest soils. Jour. Agric. Res. 46: 997-1014. 1933.

litter may possibly be required to break rain impact than hardwood litter because of the open lattice-like nature of the former.

General Discussion and Planting Implications

Normal recovery of a depleted, eroded soil in the central hardwood belt involves development of a litter cover, cessation of erosion, amelioration of physical soil structure with attendant increased infiltration rate, development of soil porosity, and incorporation of organic matter into the surface mineral soil to a depth commensurate with the potentialities of the site.

From the standpoint of soil recovery sassafras fulfills all these requirements, but it must be considered only incidental to site regeneration because it has very small commercial value. It probably will never have extensive use as a preliminary planted crop, but since it is a soil builder that provides a good planting chance it should be underplanted rather than removed in the preparation of planting sites.

Black locust holds a special place among hardwoods as a nurse crop. In addition to outstanding values for this purpose locust has very real commercial value in the Midwest, where fence posts are in constant and heavy demand. Except for very shallow soils, superdrained areas, and land with tight subsoil, conditions which occur on a substantial area, this species serves a dual purpose where the objective of planting is eventual establishment of a native hardwood forest. Probably 20 percent of the planting areas in the unglaciated portions of Ohio, Indiana, and Illinois fall within the sites suitable either for planting black locust for posts or planting other desirable hardwoods without a nurse crop in establishing the permanent forest. Probably an additional 25 percent is suitable for planting black locust primarily as a nurse crop in furnishing planting cover for and stimulating the growth of desirable hardwood species intended for the permanent forest.

The species lays down an abundant quantity of light feathery litter that stops surface soil erosion and makes possible amelioration of physical soil structure and increased infiltration rate. The litter has a high nitrogen content and decomposes so rapidly in contact with moist soil that it does not, like litter of other hardwoods, become incorporated to enrich the mineral soil with humus and stable nitrogen. Only the light, feathery, quick-drying nature of the litter prevents its rapid and complete decomposition. Rapid release of soluble salts and especially of large quantities of soluble nitrates from the portion that does decompose, however, makes black locust of special value as a preliminary crop if the stand is properly managed.

Soluble nitrates stimulate growth of trees of other species associated with black locust. If seed trees of desirable hardwoods are near by, or if the locust is underplanted with desirable hardwoods, the locust is eventually superseded and hardwood forest conditions established. Development of the hardwood understory can be hastened by judicious thinning for posts. If no native hardwood seed trees are present and underplanting is neglected the locust overstory will eventually open up naturally or by cutting, and grasses will invade the forest floor and sometimes form a sod. If locust is planted as a temporary crop, provision should be made in management plans for succession of other hardwoods.

Pines are especially suitable on temporarily depleted soils of good hardwood potentialities where current erosion is not severe, but where present surface soil conditions are not good enough for native hardwoods. These are the abandoned fields, particularly on ridges and hot dry slopes, where erosion has removed most of the surface soil. They include also shallow soils with subsoil exposed or less than 6 inches from the surface, and excessively drained soils such as coarse sands and hackly shales. Such difficult areas are not quite good enough for black locust and altogether unsuitable for immediate planting of native hardwoods. Shortleaf pine within its range is a species particularly suited as a preliminary crop before native hardwoods, because its light crown density permits hardwoods to come in sooner than do many other conifers. Outside the range of shortleaf pine, where white, red, or other pines are used, the denser crown canopies of these species are not so favorable to natural hardwood reproduction, and in such instances succession of the native forest cannot begin until thinnings and other cuttings reduce the density of these pine stands.

When pine litter has covered the soil and it has become porous and absorptive, native hardwoods generally invade the pine stand and eventually supersede it. Pines will grow well on good soils, too, but in the Central Region are less likely to

be permanent than on the poorer, drier soils. On the better soils if no seed sources are near and pine is not desired as the permanent crop, it may be underplanted with desirable tolerant hardwoods as the stand thins out naturally or by cutting.

Summary of Experimental Results

1. When the quantity of litter became fairly constant, at 21 to 35 years under good stocking, sassafras averaged approximately 7,000, black locust 10,000, and pines 20,000 pounds per acre.

2. Well-stocked natural stands of sassafras and black locust developed a litter cover several years sooner than did pines planted with a spacing of 6 by 6 feet.

3. Sassafras caused an accumulation of organic matter in the upper mineral soil; neither black locust nor pines did so within the range of stand ages sampled.

4. Black locust did not cause a significant accumulation of stable nitrogenous material in the upper mineral soil.

5. Black locust litter decomposes rapidly and liberates to the soil the equivalent of about 60 pounds of nitrogen per acre annually under closed stands. This nitrogen is in the form of soluble nitrates and is equivalent to an annual application of over 250 pounds of pure dry ammonium sulfate per acre. If this nitrogen is not utilized currently by plants it is lost in drainage.

6. Calcium and nitrogen contents of black locust litter are about double those of sassafras and pine.

7. All species studied increased surface soil infiltration rates.

8. Of the 3 species studied, sassafras contributes most completely to restoration of a hardwood forest soil. However, because of limited economic value the place of this species in reforestation is primarily that of a nurse crop which when well developed should be underplanted unless natural seed sources are near by.

9. Black locust contributes indirectly to soil restoration by improving soil structure and stimulating the growth of associated species. Due to these advantages and its economic value, black locust may be planted on the best old-field soils for the forest products obtainable, and as a nurse crop on intermediate sites where locust products may be secondary to later replacement by natural seeding or by underplanting.

10. Pines, also valuable for their products, are most useful on the drier old-field soils. They endure these site conditions, improve physical soil structure, and hence increase the rate of water absorption. In accomplishing this, they prepare the way for eventual succession of native hardwoods.